Biological and Physiological Adaptations of Birds

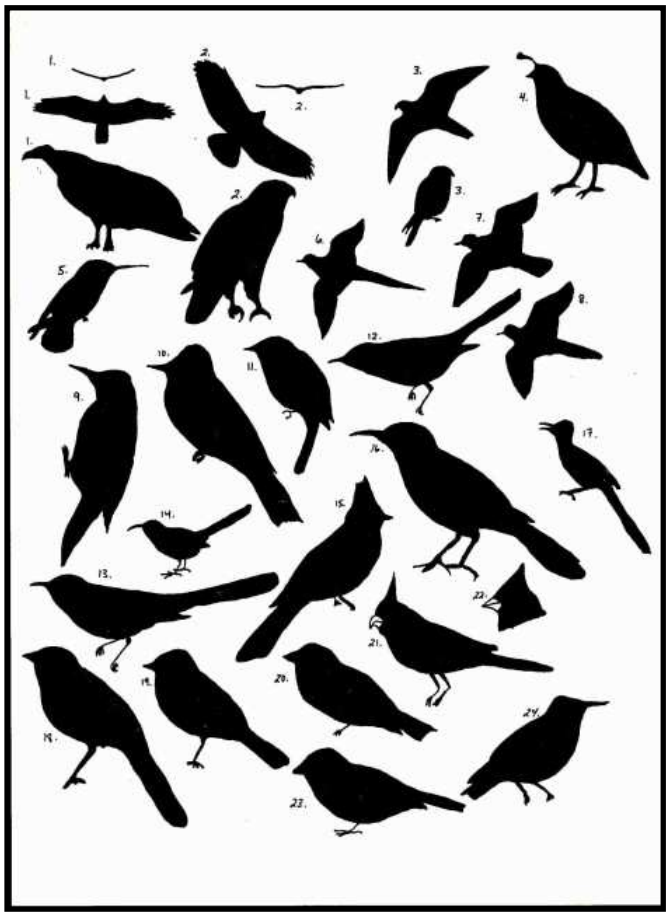
Objectives

- Understand birds' place in the animal kingdom
  - Where did birds come from?
- Understand adaptations that make flight possible
  - Skeleton
  - Musculature
  - Respiratory System
  - Circulatory System
  - Digestive System
  - Reproduction
  - Senses
  - Feathers

Class Aves

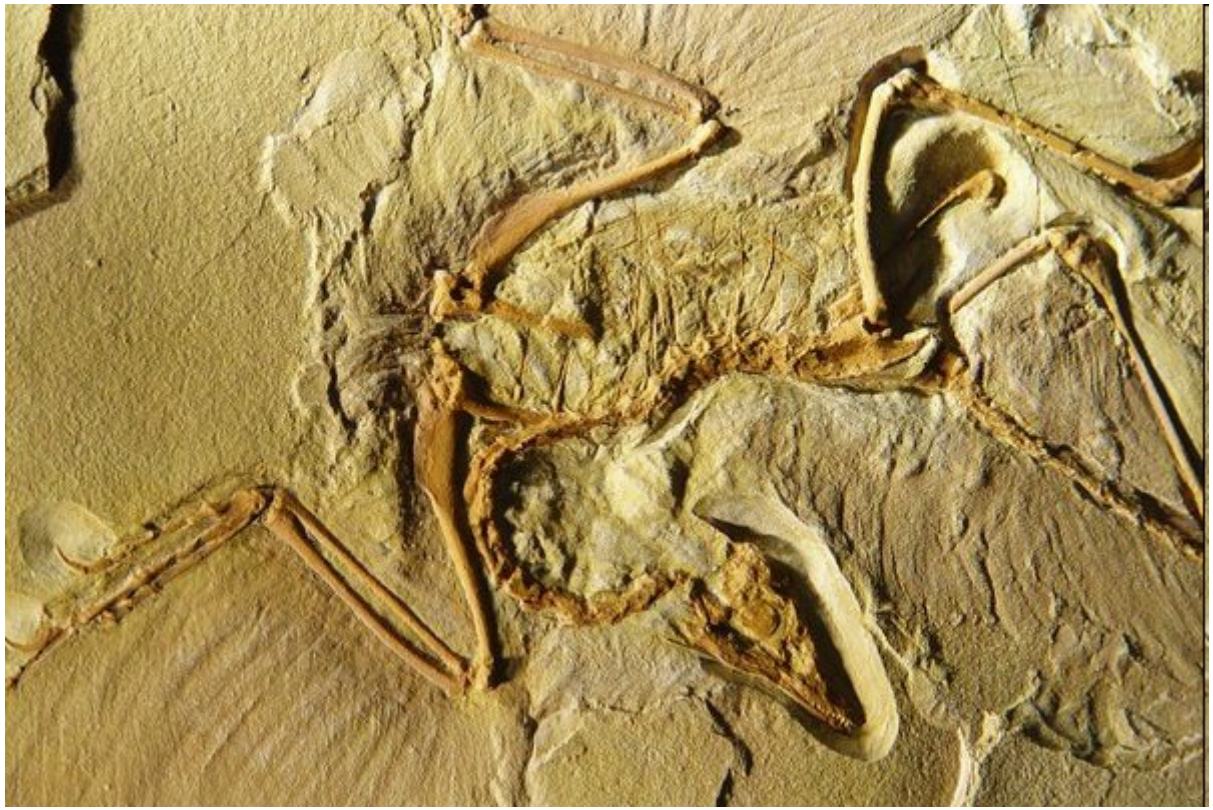
- In scientific taxonomy, birds are members of
  - Kingdom: Anamalia
  - Phylum: Chordata
- At the next level, birds are put into their own group
  - Class: Aves

Class Aves

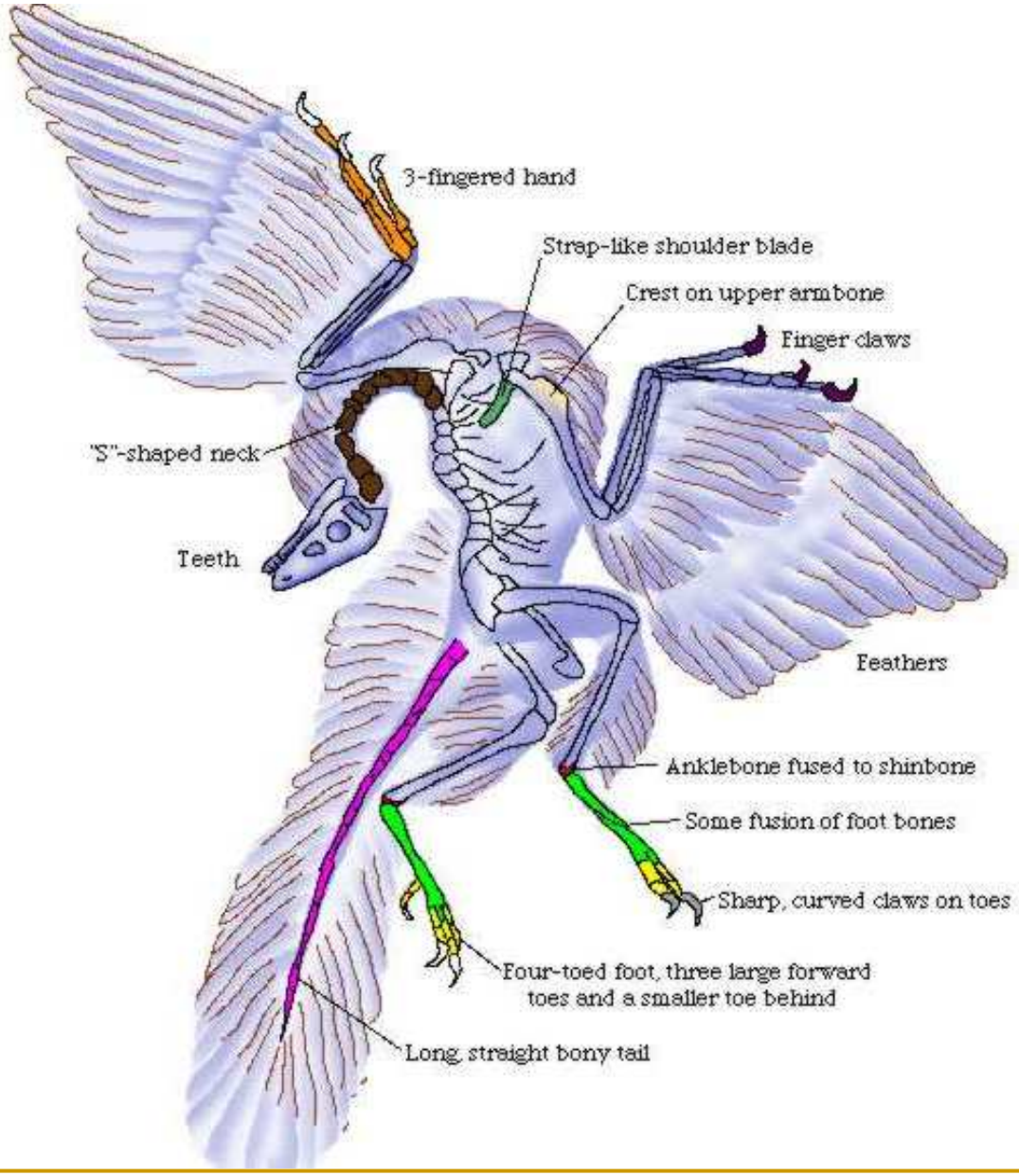


- Worldwide, there are 27 orders of birds
- Within those orders, there are hundreds of bird families
- Within those families, there are approximately 10,000 species of birds

Fossil Record



Archaeopteryx

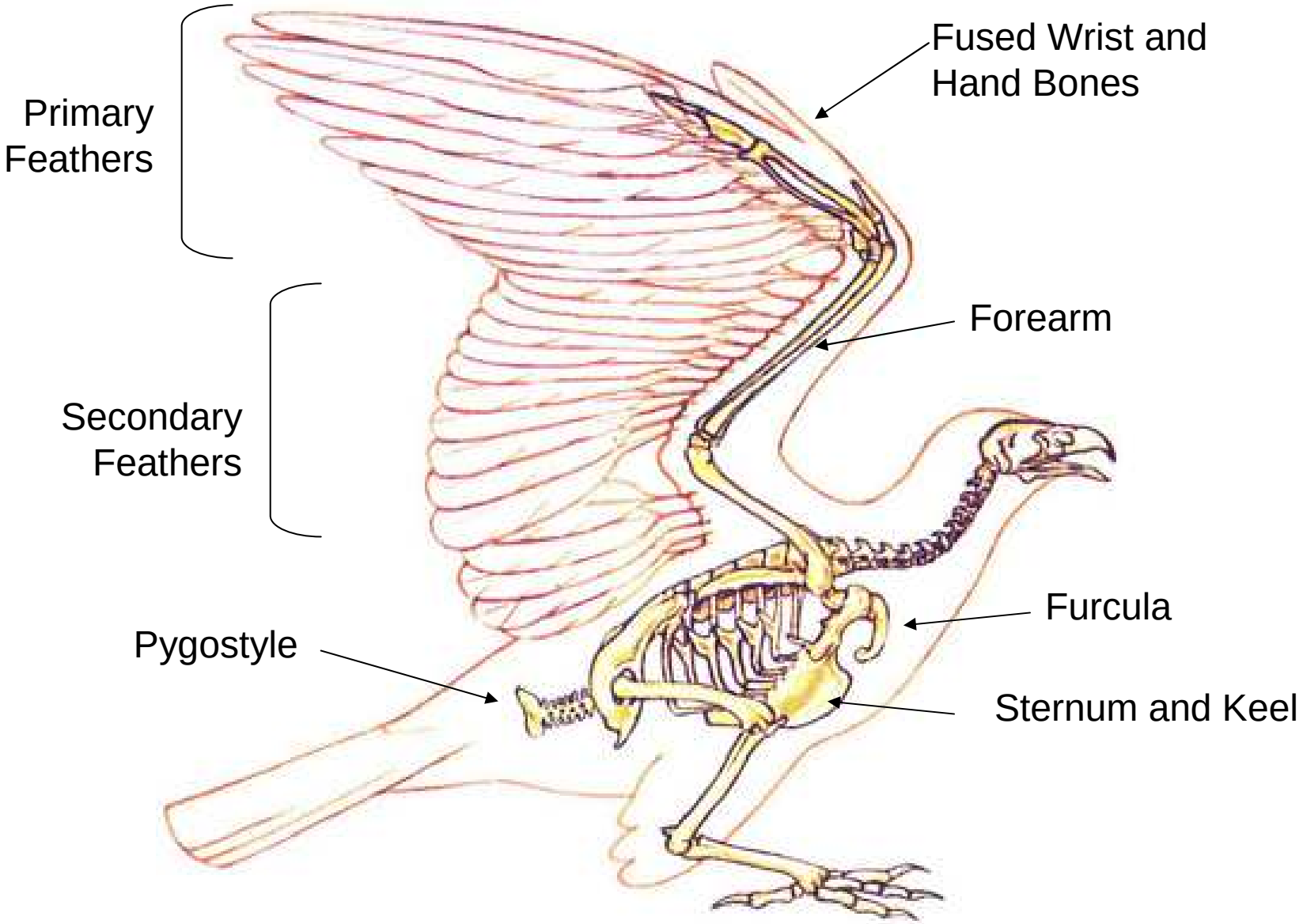

3-fingered hand
Strap-like shoulder blade
Crest on upper armbone
Finger claws
"S"-shaped neck
Teeth
Feathers
Anklebone fused to shinbone
Some fusion of foot bones
Sharp, curved claws on toes
Four-toed foot, three large forward toes and a smaller toe behind
Long, straight bony tail

Adaptations

- Almost every feature of a bird's anatomy has evolved in order to make flight possible
  - Skeleton
  - Musculature
  - Respiratory System
  - Circulatory System
  - Digestive System
  - Reproduction
  - Senses
  - Feathers

Skeletal Adaptations

- The sternum (breastbone), bears a prominent keel where the flight muscles attach
- The furcula (wishbone), serves as a brace during the flight stroke
- Secondary feathers of the wing are supported by the forearm
- Wrist and hand bones are fused to provide firm support for the primary feathers


Primary Feathers
Secondary Feathers
Fused Wrist and Hand Bones
Forearm
Furcula
Pygostyle
Sternum and Keel

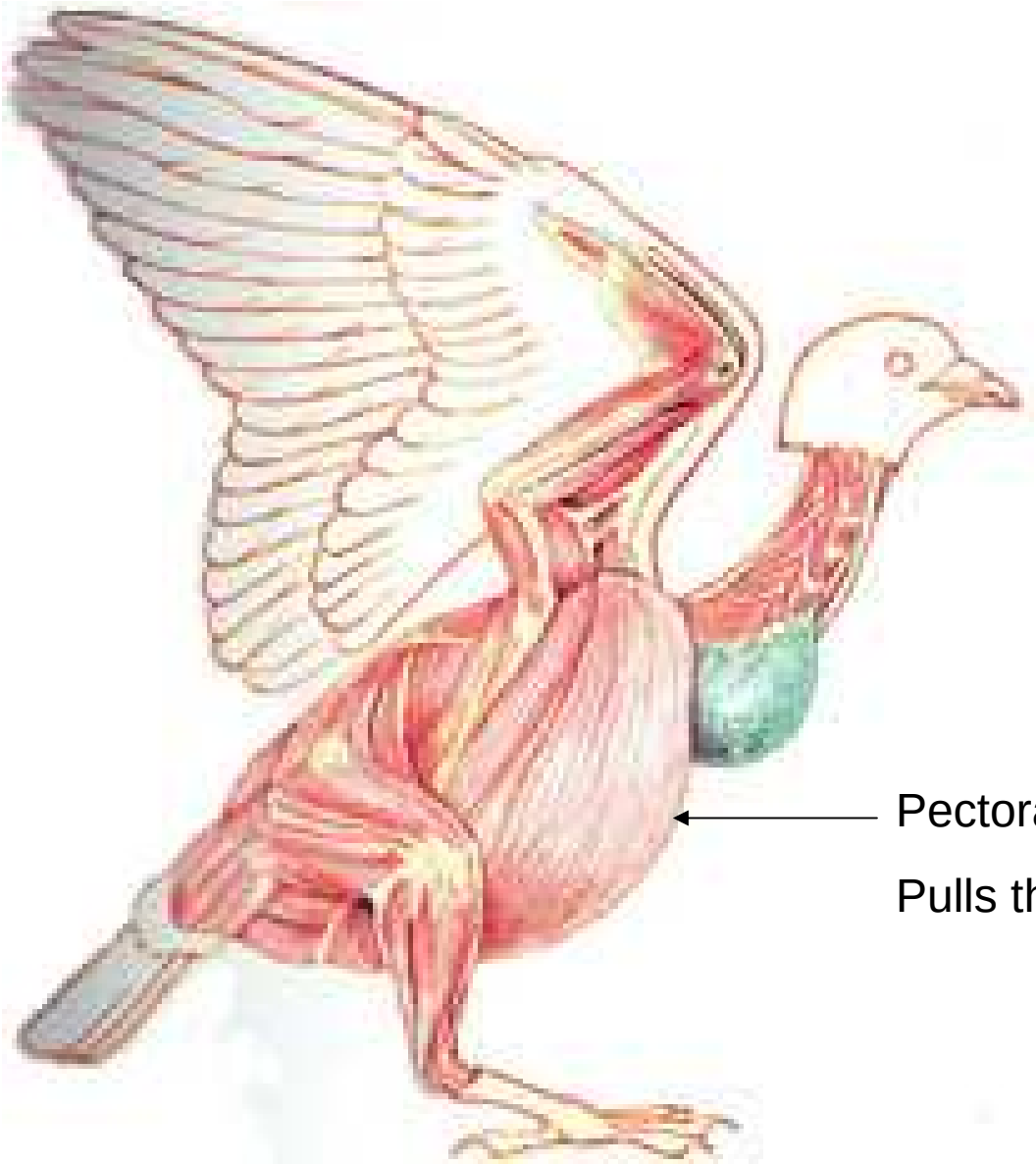
Skeletal Adaptations

- Solid bones replaced with hollow bones
  - Thin internal struts for extra strength where necessary

- Bones of the skull are extremely thin
- Teeth replaced by a horny bill

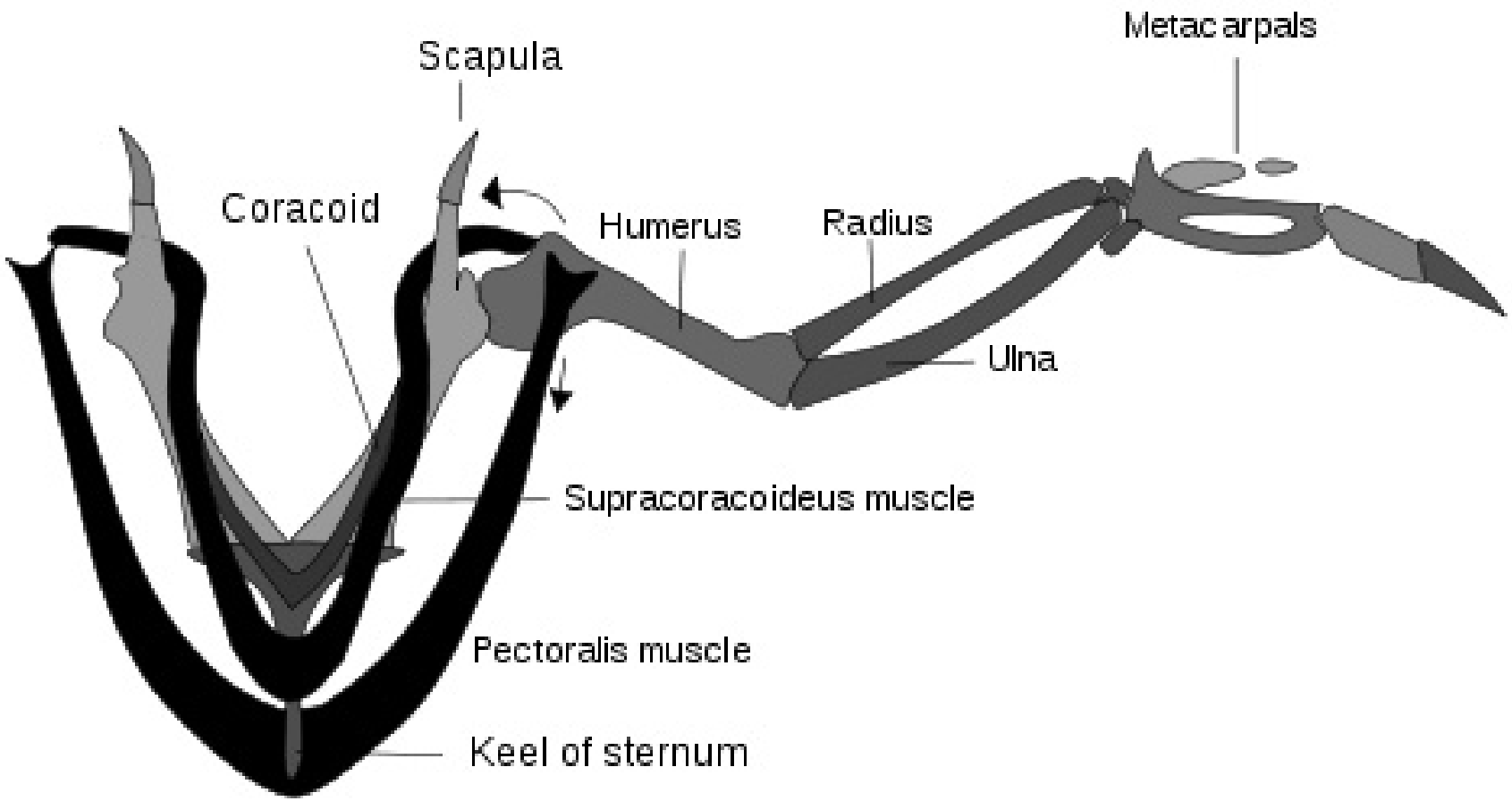
Light but Powerful Musculature

- Most birds have approximately 175 different muscles, mainly controlling the wings, skin, and legs
- The largest muscles control the wings and run between the upper arm and the keel
  - The pectoralis major provides the powerful downstroke
  - The supracoracoideus muscle raises the wing
    - Uses a pulley-like system to lift the wing
  - These muscles constitute about 20 – 25 percent of the bird's total body mass



Pectoralis major

Pulls the wing down


Metacarpals
Scapula
Coracoid
Humerus
Radius
Ulna
Supracoracoideus muscle
Pectoralis muscle
Keel of sternum

Respiratory System

- Due to the high metabolic rate required for flight, birds have a high oxygen demand
- Birds ventilate their lungs by means of air sacs
  - These structures are unique to birds, and perhaps dinosaurs, too
- Birds' lungs obtain fresh air during both exhalation and inhalation
- Birds lack a diaphragm
  - The entire body cavity acts as a bellows to move air through the lungs
  - The active phase of respiration in birds is exhalation, requiring muscular contraction

Respiratory System

- Air flows through the air sac system and lungs
  - There is no mixing of oxygen-rich air and oxygen-poor, carbon dioxide-rich air as in mammalian lungs
- The partial pressure of oxygen in a bird's lungs is the same as the environment
  - Birds have more efficient gas-exchange of both oxygen and carbon dioxide than do mammals

Circulatory System

- Birds, like mammals, have four-chambered hearts
  - Makes possible a double circulation
  - Blood makes a side trip through the lungs for gaseous purification before it is circulated through the body
- Bird's heart is large, powerful, and rapid in its beat

Circulatory System

Animal	Heart as % of Body Weight	Heart Beats per Minute
Boa constrictor	0.31	20
Bullfrog	0.32	22
Man	0.42	78
Dog	1.05	140
Vulture	2.07	301
Crow	0.95	345
Sparrow	1.68	460
Hummingbird	2.37	615

Digestive System

- A bird's digestive system can assimilate food at an extremely rapid rate
- Most birds have digestive tracts adapted to their diet
  - Herbivores
  - Carnivores
  - Omnivores

Digestive System

- Herbivores
  - Feed on seeds, fruit, and other vegetable matter
  - Have a storage sac called the crop where food is macerated before it passes to the two-chambered stomach
    - Mixed with digestive juices in the first part
    - Ground into a pulp in the second part (the gizzard)
  - Herbivorous birds swallow small stones which assist the grinding of food in the gizzard

Digestive System

- Carnivores
  - Feed on fish, animals, insects, and carrion
  - Do not usually have a crop
    - If they do, it is small
  - The gizzard is less muscular
    - Functions as a normal stomach
  - Some carnivores do not attempt to digest the bones and fur or skin of their prey
    - Regurgitated in the form of a hard pellet

Digestive System

- The pancreas is slightly more well developed in birds than in mammals
  - Possibly as partial compensation for the lack of saliva and chewing
  - It produces enzymes for digesting carbohydrates, fats, and proteins
- The liver has two distinct lobes each with its own duct leading into the small intestine
  - Stores the bile
    - In birds, the bile is acidic and not alkaline as it is in mammals

Excretory System

- Another weight reducing adaptation in birds is the absence of
  - A urinary bladder
  - A urethra
- The kidneys excrete nitrogenous wastes in the form of uric acid

Adaptations of the Reproductive System

- Birds are the only class of vertebrates in which no species give birth to live young
- Nearly all species possess only one ovary and oviduct
- They lay their eggs in the nest soon after the eggs are formed
- Reproductive structures atrophy during the non-breeding season

Vision

- Birds have acute eyesight
  - Hawks are able to discriminate fine details at a much greater distance and much more quickly than humans
- Hawks have a bony "brow" above the eye known as a *supraorbital ridge*
- Raptors including owls have a "third eyelid" known as a *nictitating membrane*
- Eyes of a bird are relatively large

Hearing

- As an adaptation for flight, birds lack an externally visible ear
- The range of hearing in many species of birds is comparable with that of mankind
- Some birds have hearing that is much more sensitive than ours
- Owls not only are more sensitive to small sounds but they have asymmetrical ears
  - Allows them to pinpoint the source of a sound extremely accurately

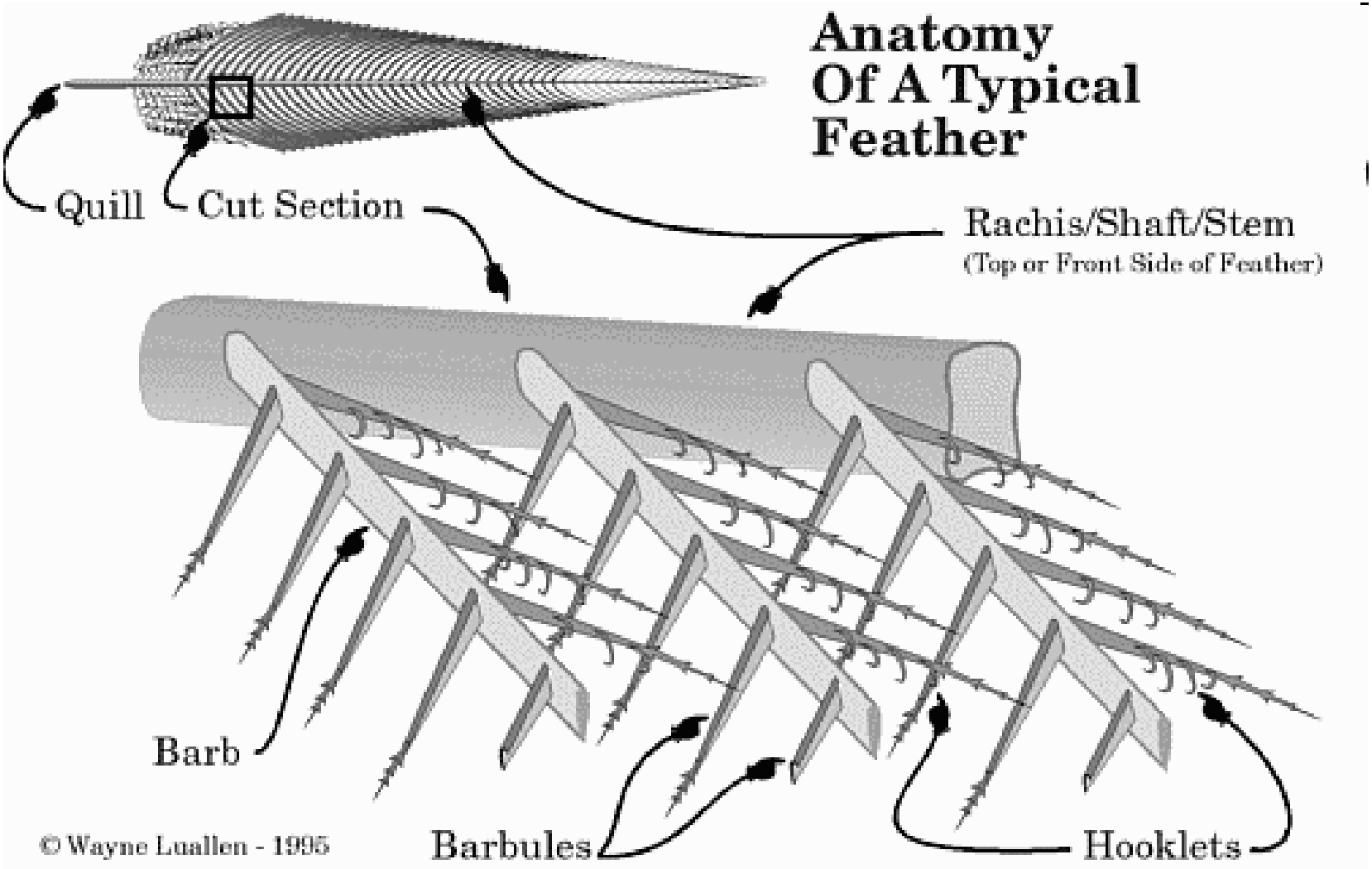
Smell

- The olfactory lobes of most birds are very small, suggesting that they have a poor sense of smell
- Some birds do use smell to locate food
  - Sea birds (Petrels, Shearwaters)
  - Vultures
  - Kiwis

Feathers

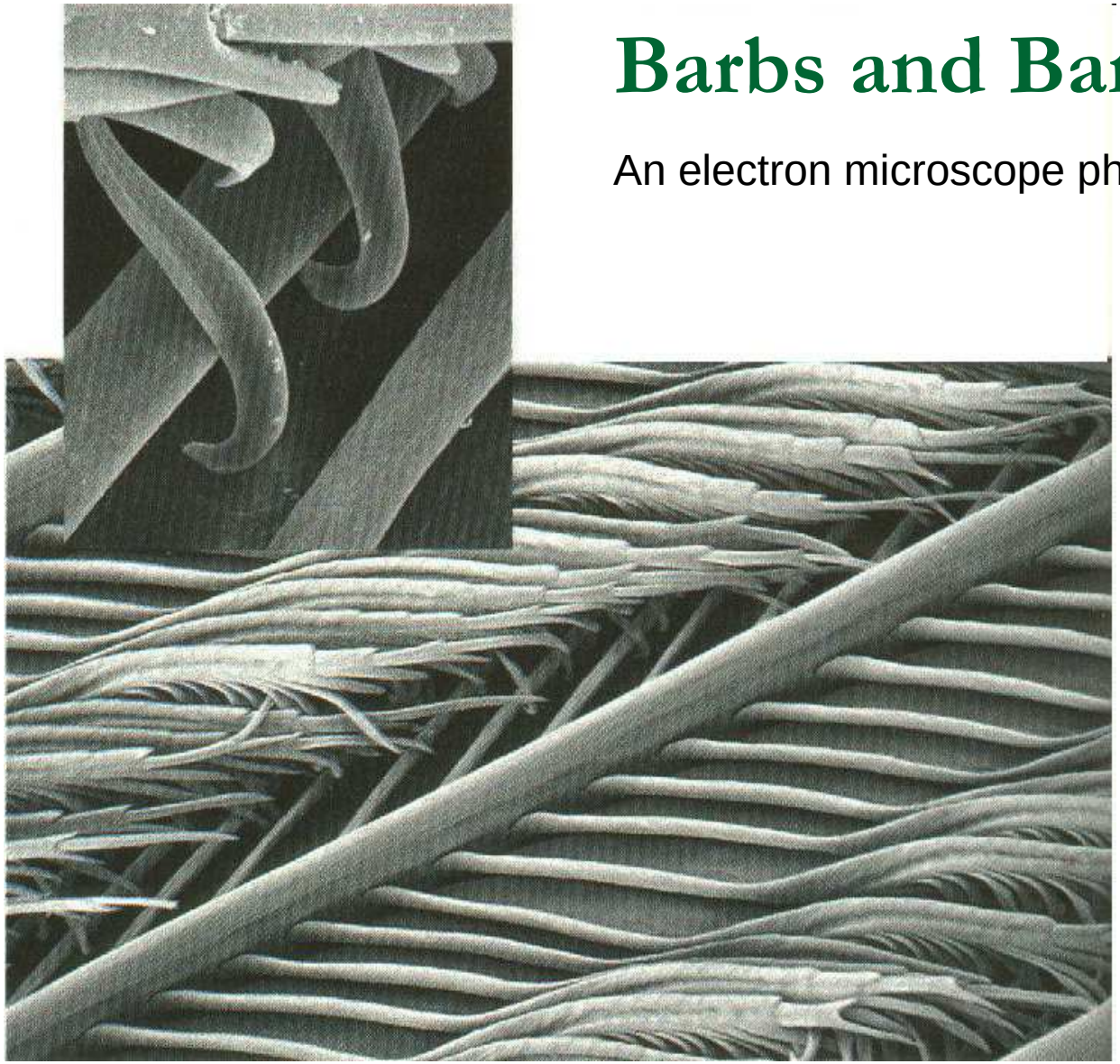
- Of all the organisms on earth, only birds have feathers
  - They are instrumental in flying
  - They play a critical role in temperature regulation
  - Their color patterns are essential in both display and camouflage

Feathers


Anatomy
Of A Typical
Feather
Quill
Cut Section
Rachis/Shaft/Stem
(Top or Front Side of Feather)
Barb
Barbules
Hooklets
© Wayne Luallen - 1995

Barbs and Barbules

An electron microscope photograph



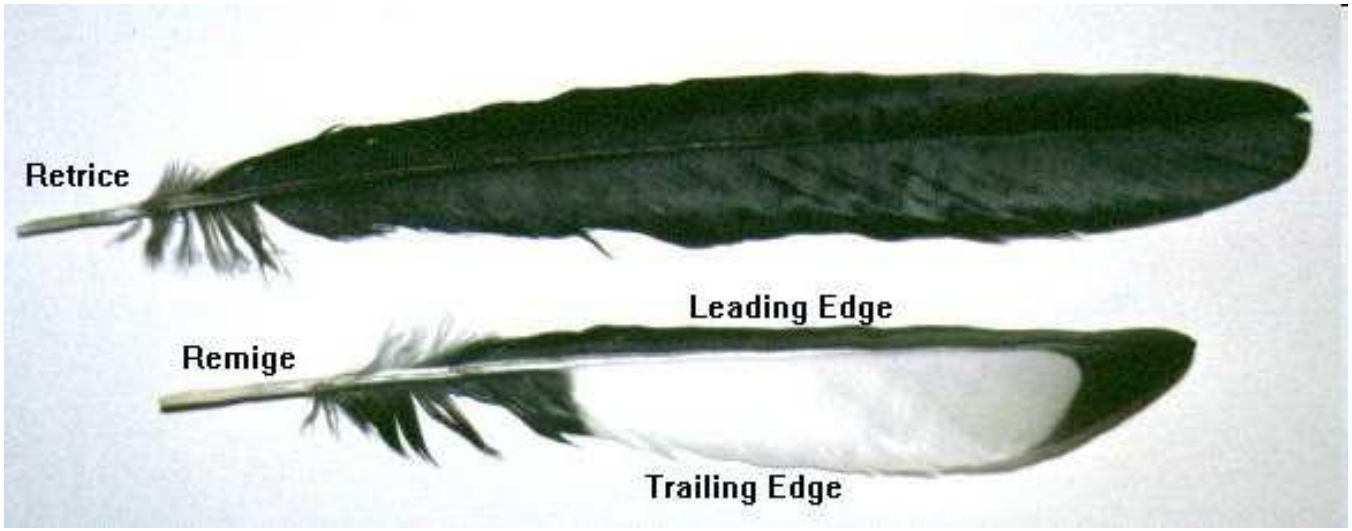
Feathers

Photo © Bob Fairey

- The number of feathers on a bird's body varies
  - Around 1,000 on a hummingbird
  - More than 25,000 on a swan

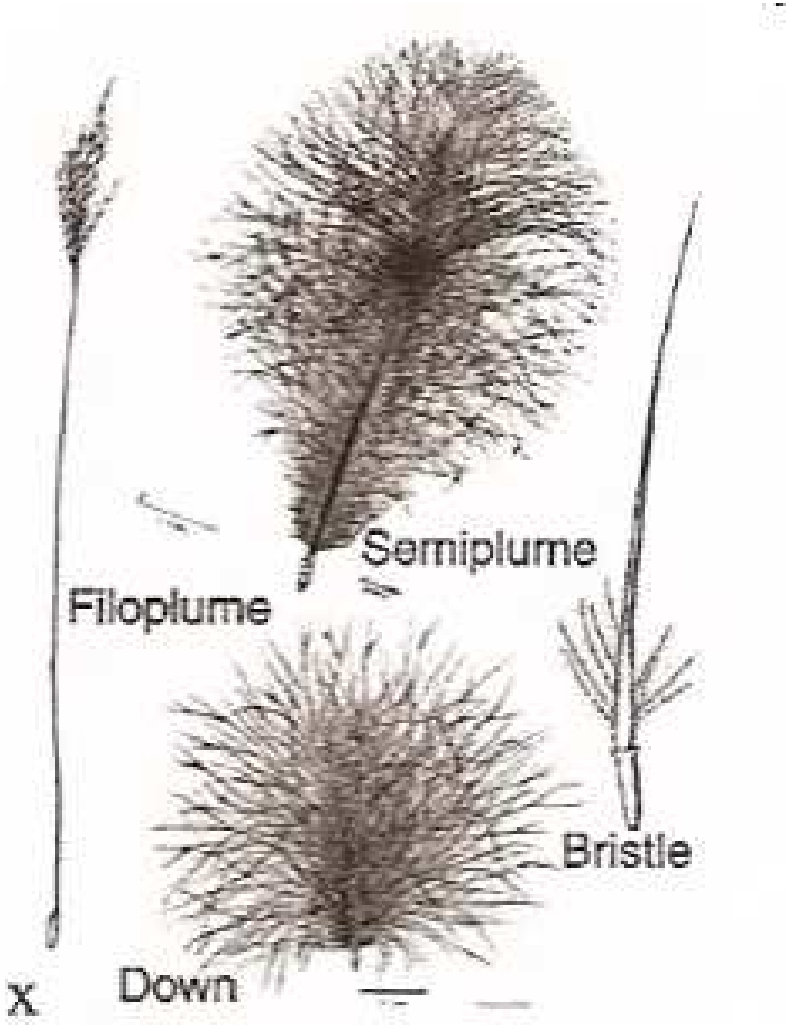
Feather Types

- Flight feathers
  - Feathers of the tail (retrices)
  - Long feathers of the wing (remiges)
    - Primaries
    - Secondaries

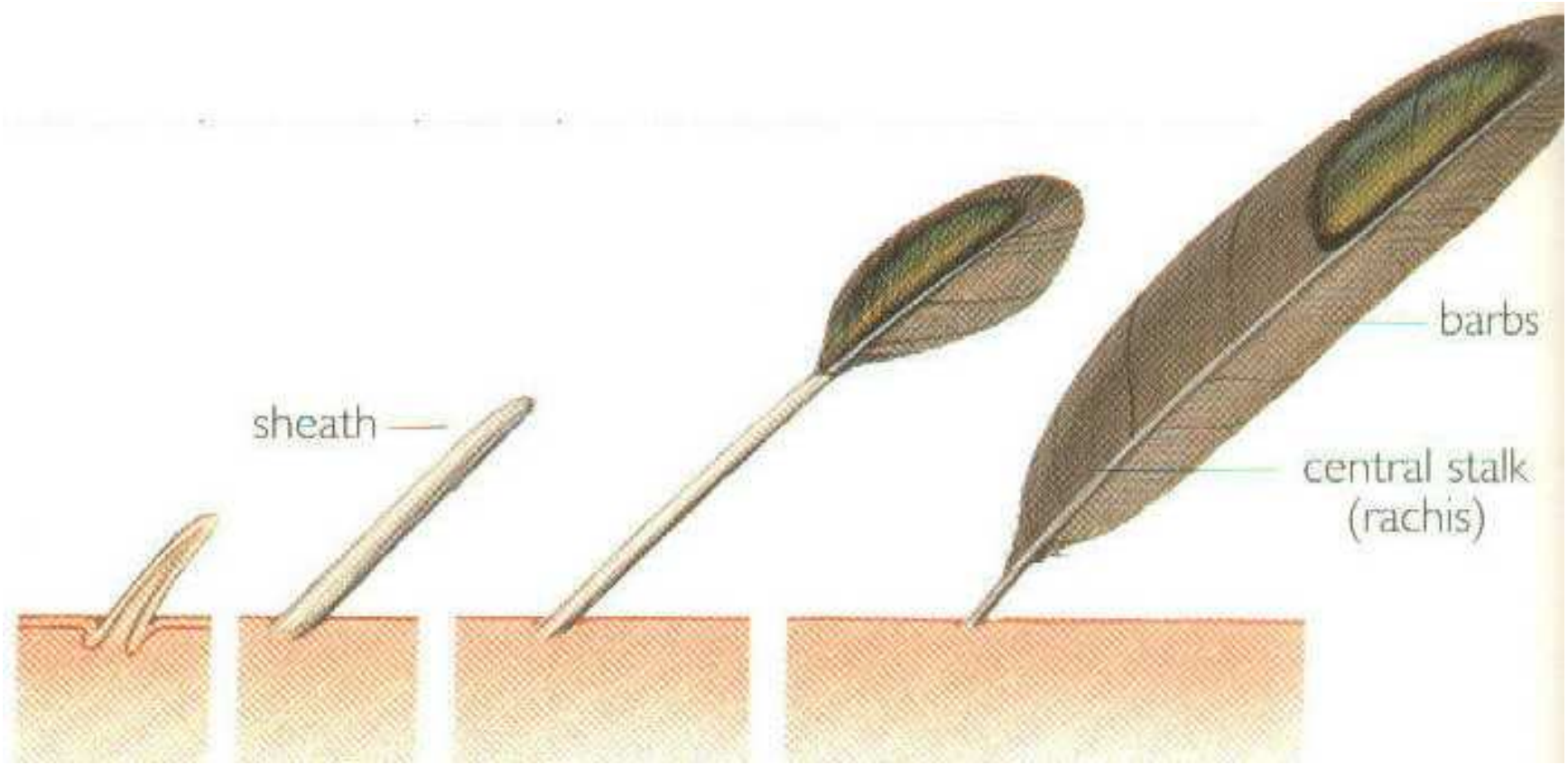


Feather Types

- Contour feathers
  - Coverts
  - Down
  - Semiplumes



How a Feather Grows



Feathers

- The mass of feathers on a bird's body constitutes its plumage
- Feathers clump in distinct tracts with featherless areas in between
  - Birds' color patterns are built of these units
- Worn feathers are periodically replaced through a process called "molt"
  - A knowledge of molts and plumages is useful for bird identification

Crested Argus Pheasant

Summary Questions

Resources

Books

The Life of Birds, by Joel Carl Welty

Birds: Their Life, Their Ways, Their World, by Dr. Christopher Perrins, and Dr. C.J.O. Harrison, published by Reader's Digest

The Sibley Guide to Bird Life and Behavior, edited by Chris Elphick, John B. Dunning, Jr., and David Allen Sibley

The Nature Company Guide to Birding, by Joseph Forshaw, Steve Howell, Terence Lindsey, and Rich Stallcup

Web Sites

The National Fish and Wildlife Forensics Laboratory Feather Atlas
http://www.lab.fws.gov/featheratlas/index.php

The Amazing World of Birds
http://www.earthlife.net/birds/intro.html

Introduction to the Aves
http://www.ucmp.berkeley.edu/diapsids/birds/birdintro.html